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Cardan's Suspension in China

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THE mechanical contrivance commonly styled "gimbal"[1] is known in the history of science under the term "Cardan's suspension". Although named for the celebrated Italian mathematician Jerome Cardan (Girolamo Cardano, or Latinized Hieronymus Cardanus; 1501–76), both the principle and its application were revealed and practised ages before his day. In fact, Cardan himself lays no claim to originality in this invention, but in his work *De subtilitate rerum*, first published in 1551, he merely describes a chair constructed for an emperor, which permitted him to sit in it during a drive without experiencing the least jolting, and on this occasion observes that the same arrangement had been used previously in connection with oil lamps.[2]

As intimated by Berthelot, Cardan must have encountered the invention bearing his name in the writings on the secret processes of magic, to which he was not foreign. Not only was he a philosopher, a physician, and a devotee of science, but also an astrologer, charlatan, and gambler.[3] We now even possess a clew to this magical document presupposed by Berthelot, as will be seen farther on.

The nearest predecessor of Cardano was Leonardo da Vinci (1452–1519), who left a design showing the suspension of a body, said to be capable of turning itself around three axes perpendicular one to another.[4] This construction, however, is not due to Da Vinci's genius either, for, as first shown by M. Berthelot,[5] the great French historian of chemistry, it was well known during the early middle ages. The document on which Berthelot's opinion is founded is contained in a curious Latin manuscript, the *Mappæ clavicula* (that is, "Key

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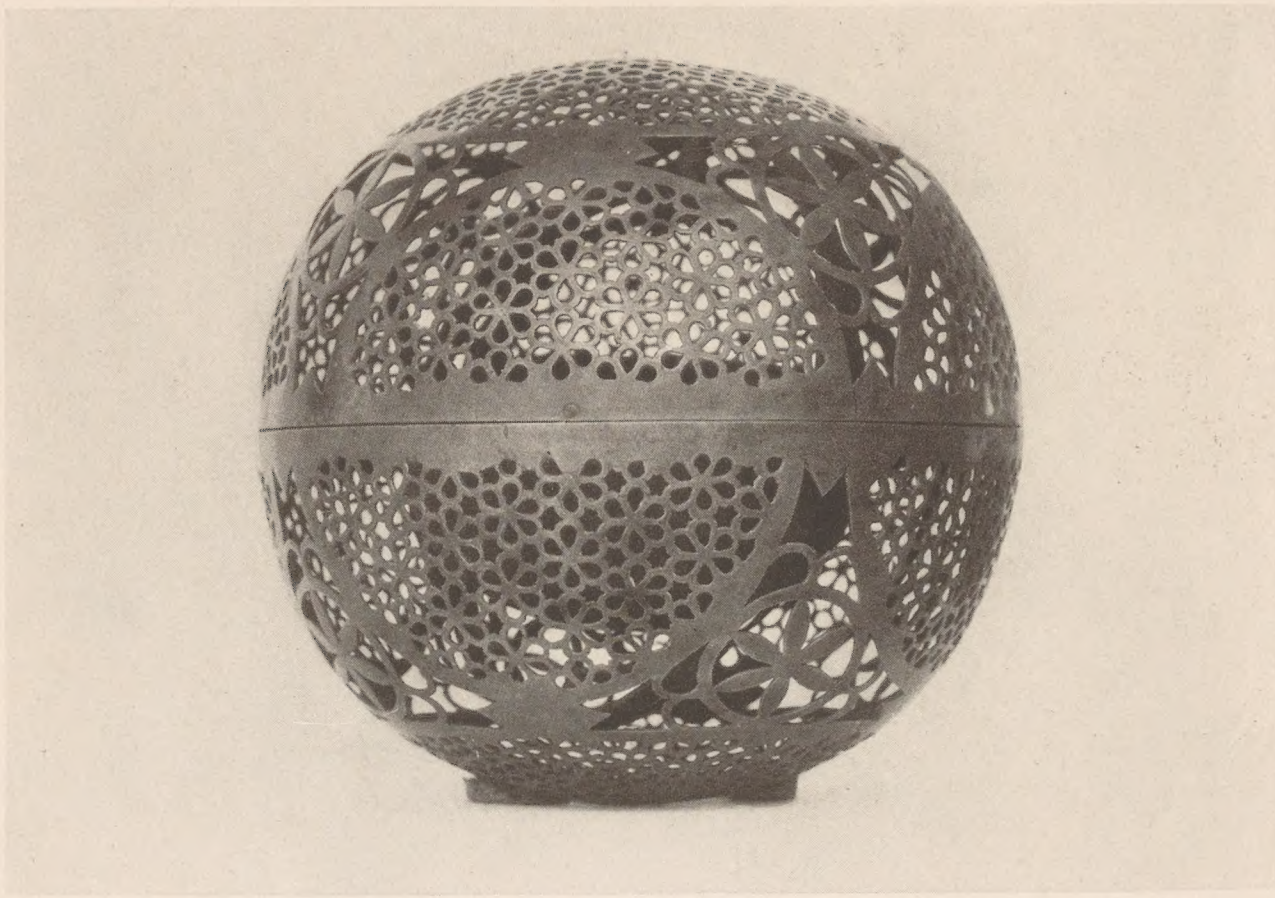
[1] Derived from Old French *gemel*, which is based on Latin *gemellus*, diminutive of *geminus* ("double", "twin"). The New Oxford English Dictionary gives the following definition of the term: "A contrivance by means of which articles for use at sea (esp. the compass and the chronometer) are suspended so as to keep a horizontal position. It usually consists of a pair of rings moving on pivots in such a way as to have a free motion in two directions at right angles, so as to counteract the motion of a vessel."

[2] Compare F. Cajori, A History of Physics, p. 24, New York, 1899.

[3] As is also well known, the solution of the cubic equation known as Cardan's method is not due to his merit, but was the discovery of his countryman Tartaglia, who communicated it to Cardan in 1541, whereupon the latter published the solution under his own name.

[4] E. Gerland, Geschichte der Physik, p. 250.

[5] First in *Comptes-rendus de l'Académie des Sciences*, vol. CXI, 1890, p. 940; then in La Chimie au moyen âge, vol. I, pp. 176, 177, Paris, 1893.



CHINESE BRASS BRAZIER IN CARDAN'S SUSPENSION. DIAMETER 18.7 CM.
(Field Museum of Natural History, Chicago, cat. no. 117679)

to Painting"), treating in the main of recipes giving substitutes for gold and silver, recipes for writing in gold and silver, purple dyeing and technique of pigments. The work is of especial importance for the first indubitable mention of alcohol. It is extant in an English manuscript of the twelfth century edited by Sir Thomas Phillipps in *Archæologia*,[1] and in a German manuscript of the tenth century in Schlettstadt, found by A. Giry in 1877. H. Diels[2] dates the compilation of the Latin work in the time of Charles the Great, on the basis of linguistic arguments, and, like Berthelot, traces its contents to the Alexandrian school of alchemists. The text of the mediæval book in many cases agrees exactly, even in particulars, with the sources of Greek alchemy; and if more of these had been preserved to us, the coincidences would presumably be still more numerous. This point of view should be emphasized, as the ideas emanating from the *Mappæ clavicula* point straight to Alexandria. The passage relative to a suspension à la Cardan is embedded in a series of recipes for magicians or jugglers, and runs as follows: "Given four concentric circles revolving the one about another, so arranged that their diameters coincide; if a vase is suspended in their interior, in whatever way they may be turned, nothing will be spilled." Berthelot thought it probable that this idea would be traceable to Greek physicists, but at that time could not prove his supposition. In this estimate, however, he was not mistaken, for about a decade later the fact was established in the writings of Philo of Byzantium, a Greek mechanician who in all probability lived in Alexandria during the third century B.C.[3] His work on mechanics (μηχανικὴ σύνταξις) is lost, except the fourth book dealing with military engines (the oldest extant work on artillery) and excerpts from the seventh and eighth books. The fifth book on pneumatics is preserved in the Latin translation of an Arabic manuscript and in an Arabic recension. The latter has been edited and translated by Baron Carra de Vaux. Here we read in article 56 as follows: "Construction of the octagonal inkwell, a very elegant apparatus. We make an inkwell octagonal, hexagonal, square, pentagonal, or whatever form may be given to prismatic glasses. This inkwell has on each side a place whence ink may be drawn, and in whatever position this object is placed, its upper face presents you an opening for the introduction of the pen without anything being overturned. The pen is dipped in, it meets the ink, and you write

[1] Vol. XXXII, 1847, p. 187.
[2] Die Entdeckung des Alkohols, *Abhandlungen Preuss. Akad.*, 1913, pp. 6–17.
[3] W. Schmidt, Heronis Alexandrini opera, vol. I, p. lxx; F. Susemihl, Gesch. d. griech. Lit. in der Alexandrinerzeit, vol. I, p. 744. Others assign his lifetime to the second century B.C. The problem is still controversial.

with it. For instance, compare this hexagonal inkwell as you see (fig. 1). In the interior is a collar on a pivot $\alpha\beta$; in this collar is another on a pivot $\gamma\delta$; in this interior of the second chain is a cup on a pivot $\epsilon\zeta$, and this cup forms the inkwell. One might say this is the Jewish style and the construction of the apparatus resembles that of the censer which turns while remaining at equilibrium. Measure this construction well and adjust it carefully, so that every time you place the inkwell on any face, that which is presented for the entrance of the pen is the top of the inkwell." The manuscript of Oxford adds to the figure the following comment which must be a subsequent interpolation: "This movable apparatus is like the throne of Solomon, the son of David. When somebody familiar with Solomon's throne makes use of it and ascends it, he will remain there; a person unfamiliar with

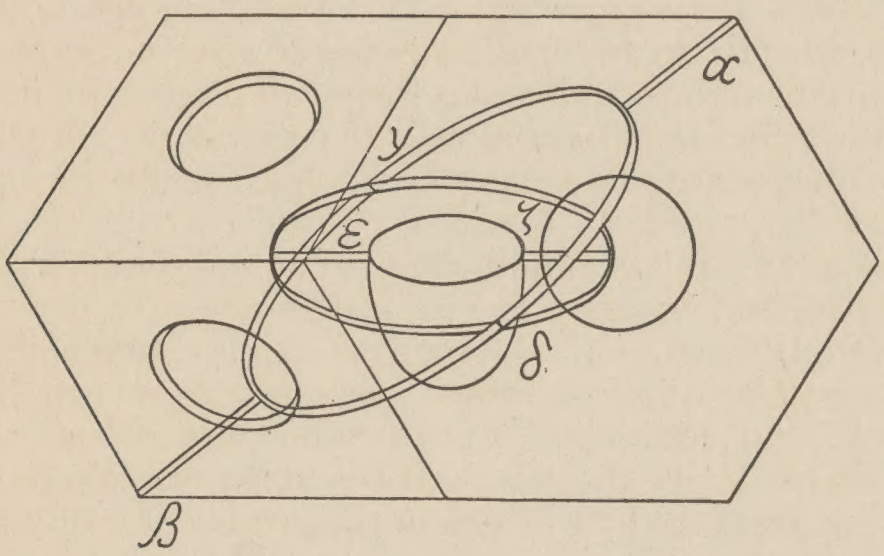


FIG. 1.—Philo's Inkwell in Cardan's Suspension (after Baron Carra de Vaux).

it, who will sit down in it, will fall to the ground. This is very nice."[1] Here we have a magical source like the one from which Cardan may have derived his description of the suspended imperial chair. In his introduction (p. 36) Carra de Vaux discusses the question of possible interpolations in the Arabic version and makes this observation on our passage: "The most curious article is that of the suspended inkwell which is found both in the manuscript of St Sophia in Constantinople and in the anonymous collection of Oxford. This inkwell is based on a suspension à la Cardan. It is somewhat astounding that

[1] Baron Carra de Vaux, Le livre des appareils pneumatiques et des machines hydrauliques par Philon de Byzance (tiré des *Notices et Extraits des manuscrits de la Bibl. Nat.*, vol. XXXVIII, Paris, 1902, p. 195).

this ingenious arrangement has been forgotten by Hero and the subsequent mechanicians; but it is not impossible, after all, that it should have been forgotten. The text says that this mode of suspension was utilized in the Jewish censers; some archeologist versed in Hebrew antiquities might possibly deduce a date therefrom." There can be no doubt that the description of the inkwell was part and parcel of Philo's original Greek text, and that the Arabic translation renders a correct account of it.[1] This is confirmed by the *Mappæ clavicula*, and we are fully entitled to the conclusion that the principle of Cardan's suspension was well familiar to the great Hellenic mechanicians of the Alexandrian epoch.

Whether the allusion to the Jewish censer hints at some Semitic influence can hardly be decided in the present state of our knowledge. What is of particular interest in this connection is the fact that in China also the Cardanic principle has been applied to censers or braziers.[2] Berthelot already had some vague information to the effect that "suspension à la Cardan has been employed in eastern Asia probably from times immemorial, as the Chinese do not change their processes." This point, however, he added, would require further elucidation.

The principle is well exemplified in a Chinese brazier obtained by the writer in 1909 at Si-ngan, the capital of Shen-si Province, for the Field Museum, Chicago (cat. no. 117679). In its outward appearance it presents a hollow sphere of brass, cut out into rosette-like designs in open-work, and composed of two hemispheres (see pl. 1, upper figure), one fitting above the other. If the upper one is removed (lower figure on the same plate), we notice in the interior a round brass bowl, which may be filled with aromatic substances, incense, or burning charcoal. If filled with coal, the brazier conveniently serves as a bed-warmer, as the sphere may be rolled and knocked around *ad libitum*, while the bowl swinging freely and independent of this motion will never turn upside down. The contrivance consists of two brass hoops, so arranged that one is within and perpendicular to the other. The outer hoop is riveted to two lugs, projecting from the inner side of the hemisphere and made in the same cast with it. The inner hoop moves on a pivot connecting it with the outer hoop and encircles the brass bowl. The bowl, accordingly, remains constantly suspended in a vertical position, while the rolling motion of the sphere is not com-

[1] This, so far as I know, is the generally accepted opinion. See, for instance, J. L. Heiberg, Naturwissenschaften und Mathematik im klassischen Altertum, p. 59.

[2] We still apply it to ship's lamps, the mariner's compass, and to barometers. A barometer suspended à la Cardan is figured and described by E. Atkinson, Elementary Treatise on Physics, 13th ed., p. 145, New York, 1890.

municated to it. The whole construction is very similar to the Alexandrian inkwell.

The brazier in question was attributed to the Ming period (1368–1643) by my Chinese informants of Si-ngan, and this date seems plausible. At present, this contrivance is no longer in use, at least not in northern China. According to Chinese tradition it is due to Ting Huan, a famed mechanician of the Han period (206 B.C.–A.D. 220),[1] who excelled in the making of ingenious mechanical devices, and who lived in the capital Ch'ang-ngan (now Si-ngan). He is credited with the invention of censers or braziers styled "reclining on the mattress" or "brazier in the bed-clothes", by the application of four revolving rings, so that the body of the vessel was kept at equilibrium, and could safely be placed on the bedding. This tradition doubtless refers to an instrument like the one described and figured. Its origin in the Han period is perfectly credible, as this was the era when mechanics and engineering awoke in China, and a scientific knowledge of nature gradually began to dawn. This also was the epoch when China was opened to intercourse with the West, and when along the trade-routes leading across Central Asia into the Roman Orient Hellenistic ideas and inventions were conveyed to the Chinese. Hellenism, the first universal civilization in the history of the world, based on a syncretism of Greek, Egyptian, and Semitic concepts, expanded into all directions of the globe, and Alexandria was its spiritual center. A single case certainly lacks convincing force, but the totality of coinciding phenomena with which we are now confronted is so overwhelming that Hellenistic influence on ancient China can no longer be denied. It is most obvious in the natural sciences, particularly alchemy and mineralogy, and in technology. All that is recorded of mechanical innovations in the Han period is traceable to the writings and models of the Alexandrian mechanicians. The application of Cardan's suspension is only one example, but perhaps not the least interesting.

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[1] The exact date of his lifetime is not known; more probably he lived at the time of the Later or Eastern Han dynasty (A.D. 25–220), rather than under the Former or Western Han (206 B.C.–A.D. 24). The activity of this artisan is discussed in the writer's Chinese Pottery of the Han Dynasty (pp. 196–198), where also the relevant Chinese text is cited.

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